

RADIATION ON MAGNET COILS FROM THE WIRE SEPTUM

A. I have run a Monte Carlo on protons striking 10' of wires, .002" each, .1" spacing, 1200 in all. First I followed 1000-GeV protons until they scattered out, using a 140 mil rad length (W). I collected data on the actual thickness traversed and the angle on leaving. The input position was .05 to .95 mils off center in .1 mil steps. The results are shown in diagrams. Next, I calculated the probability of interaction using 2.2" interaction length. The overall probability is 1/3.

B. Consider 2×10^{13} protons at 1000 GeV
 beam energy is 3.2×10^6 Joules.

Suppose 2% hit wires and 1/3 of these interaction
 interaction energy 2.1×10^4 Joules.

C. The γ 's from π^0 's have an excellent chance of escaping from this geometry. I estimate the energy in π^0 's by assuming it is the same as π^+ and using the Wang formula:

$P_{\text{ions}}/\text{GeV}/\text{sr}/\text{interaction proton}$

$$\frac{dn}{dp d\Omega} = A p_0 \times (1-x) \exp(-Bx^C - Dp_T)$$

$$A=2.835 \quad B=3.558 \quad C=1.333 \quad D=4.727$$

for π^+ with p 's in GeV/c, p_0 is 1000 GeV/c.

It is convenient to use u , the fraction of p_0 in place of n : $u = n \times p_0$;

and to use $dx = dp/p_0$; and to use $p_T = x p_0 \Theta$. Then

$$\frac{du}{dx d\Omega} = 2.835 x^2 (x-x) \exp(-3.558 x^{1.333} - 4.727 x \Theta)$$

per micro s.r. for $p_0 = 1000$, Θ in mrad.

Integrating over x one obtains the

Fraction of Interaction Energy/ μsr . at angle θ in π° 's

mrاد	$dv/d\Omega$	mrاد	$dv/d\Omega$	mrاد		mrاد	
0	.050	1	.0087	2	.0026	4	.00054
.25	.045	1.25	.0061	2.5	.0016	4.5	.00041
.5	.019	1.5	.0045	3	.0011	5	.00031
.75	.013	1.75	.0034	3.5	.00075	6	.00017

D. A typical geometry.

Wires at straight section center.

0 mrad hits coil of first bend about 220" into magnet at an angle of 7.3 mrad.

About last 90" of this magnet see the wires through a beam stop placed in front. The illuminated region is about $\pm .4$ " high or 14 wires total.

The distance is 41.1 M so 1 cm^2 of coil surface subtends .00043 μsr allowing for the 7.3 mrad grazing angle.

About 450 mJ of γ 's enter each cm^2 of coil surface.

The coil is .3" thick. The "straight-line" beam would travel 41" in crossing it - more than twice the length needed to contain the shower. The width however is not enough. Up and down spread is compensated by upper and lower showers. There is a strong field at the entrance surface. Reverse field in the second layer coil. Guess 1/2 of energy stays. Note the wires transpose from side to side and that the illuminated region is long. With times ≥ 1 msec we can use averages.

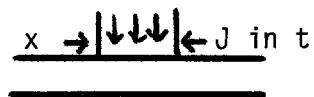
E. Some thermal properties.

The specific heat is almost the same/cm³ for Nb-Ti and copper. One can use 1 mJ/cm³/°K. The coil has an effective thickness of .6 cm so .6 mJ/cm² of surface, remaining in the coil, produces $\Delta T = 1^\circ\text{K}$.

Two cooling processes are involved

Conduction through insulated edges to He. I estimate $k = 4 \text{ mW}/^\circ\text{K}/\text{cm}^2$ where the cm² refers to 1 cm length of coil by 1 cm height, i.e. the same cm² as used in radiation input. Note that for a ΔT in t sec one loses $1/2 \Delta T k t$ during heating.

Diffusion along wire. Heat flows in and out of the Nb-Ti filaments with a time constant much less than 1 μsec . They do not conduct heat longitudinally but "load" the copper somewhat. The combined diffusion constant $D = 2000 \text{ cm}^2/\text{sec} = 310 \text{ in}^2/\text{sec}$. One can estimate the diffusion effect as follows:



Let J joules enter uniformly along a length x over time t. First calculate a diffusion length $l_d = (Dt)^{1/2}$. If

$x \gg 3 l_d$, calculate Δt from the local energy density, call this ΔT_1 (no diffusion). If $x \ll .5 l_d$ calculate as if I had entered l_d instead of x (diffusion limited), call this ΔT_d . For

$$x = l_d \quad \Delta T_{\max} = .58 \Delta T_d \quad \text{or} \quad .58 \Delta T_1$$

$$x = 2l_d \quad \Delta t_{\max} = .36 \Delta T_d \quad \text{or} \quad .72 \Delta T_1$$

For our case one can ignore diffusion for times less than $\sim 3 \text{ sec}$.

For 1 sec

$$J_{\text{mj}}/\text{cm}^2 = .6\Delta T + \frac{4}{2} \Delta T \text{ or } \Delta T = J/2.6$$

for 1 msec $\Delta T = J/.6$.

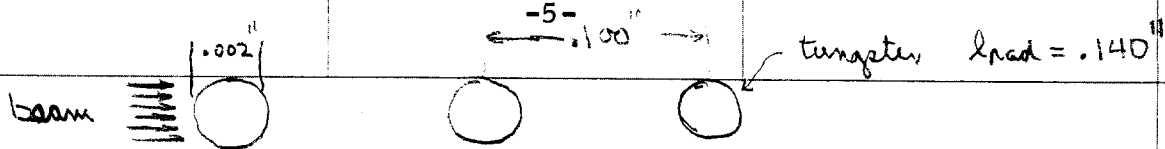
Allowable ΔT

For a magnet at the edge of quench, a small amount of heat diffusing to the high field point (in the end, for an upper or lower turn) will cause quench. A slightly lower current removes this effect because this turn does not have much heating. The central turns take over. They have the nominal field, about 10% below the peak, and can be heated by 10% ($T_c - T$) where $T_c = 10.6^\circ\text{K}$, i.e. about $.6^\circ\text{K}$. If one lowers the current this must approach 6°K so the low current-high current sensitivity ratio is another measure of the allowable ΔT . For our case one finds allowable

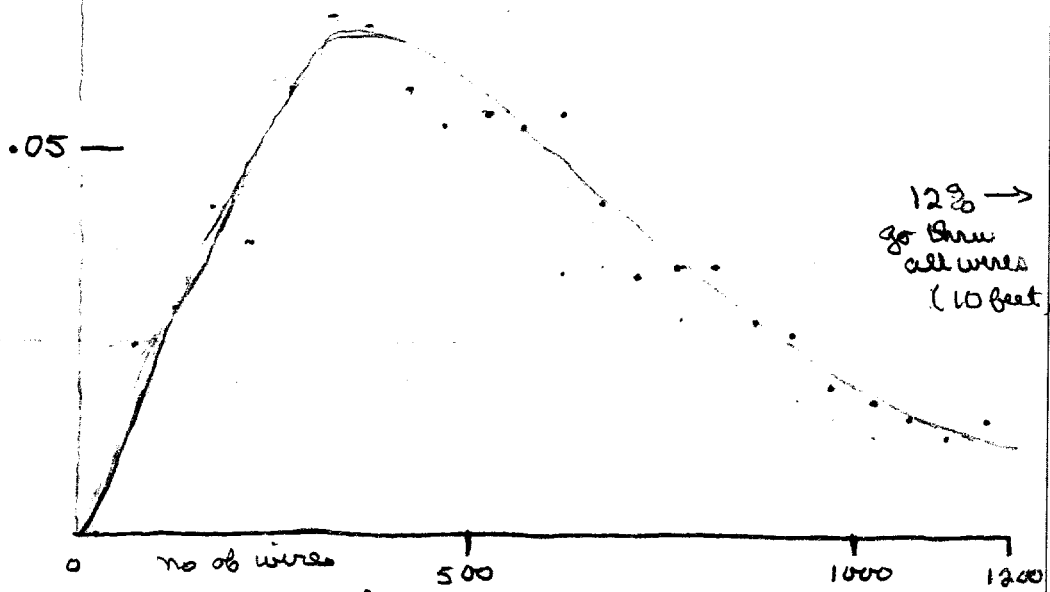
$$J = 2.6 \times .6 = 1.5 \text{ mj/cm}^2 \text{ in one second}$$

$$J = .36 \text{ mj/cm}^2 \text{ in milliseconds.}$$

Comparison of these figures with 450 mJ input makes it clear that precision estimates of shower loss are not needed. We must shield.

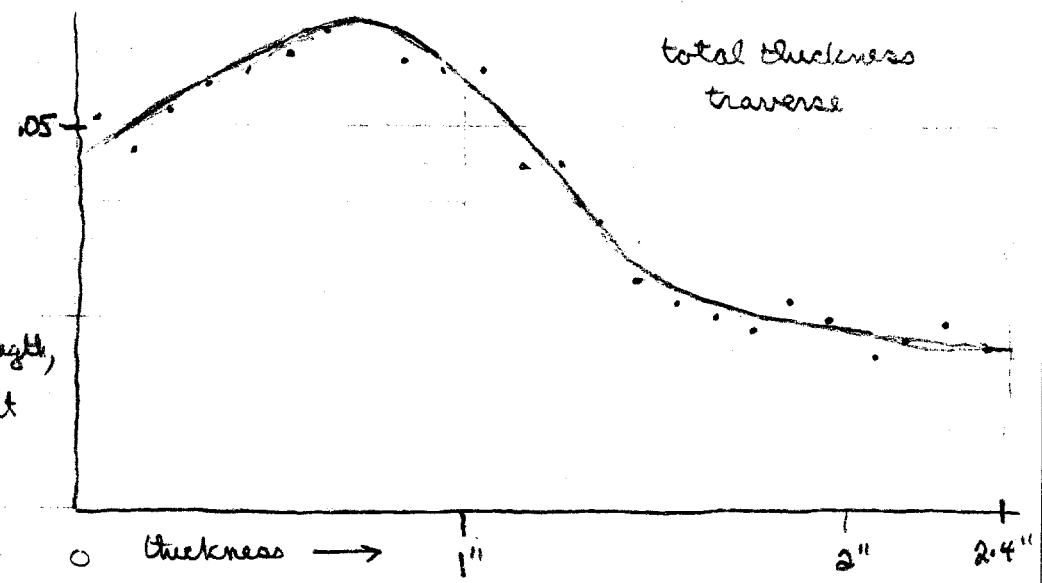


Fraction
leaving
per 50 wires



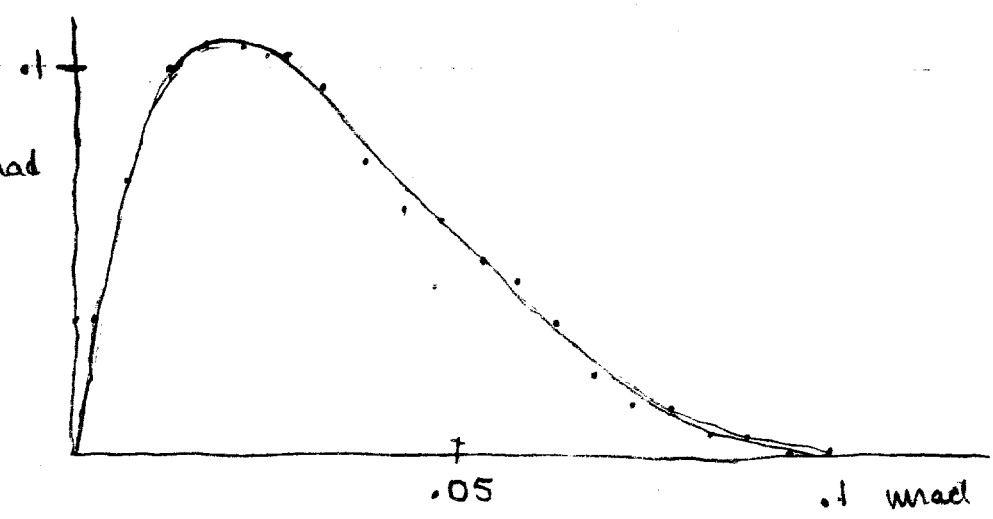
12% →
go thru
all wires
(10 feet, 1200 wires)

Fraction
per .1"



using
2.2" inter length,
.333 interact

fraction
per .005 rad



horizontal angle in degrees

288
oct 78